

Heavy Ion, Cold Nuclear Matter, and Spin Physics Programs at LANL

Melynda Brooks
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Outline:

- Support for Team Work Efforts
- Personnel
- Highlights and Future Plans
- Budget

PHENIX Team Efforts and Support



DOE Supported Efforts

Medium Energy Physics - Proton Spin and Cold Nuclear Matter studies at RHIC, (JLAB) - \$1000k/yr

Heavy Ion Physics - RHIC Heavy Ions - \$2500k/year

FVTX (LDRD covered much R&D efforts)

PHENIX Muon Tracker - continued maintenance, expert shifts, etc.

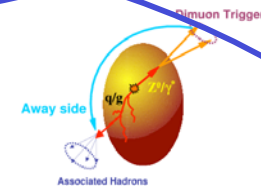
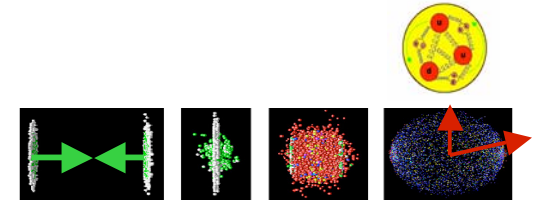


LDRD-Supported Efforts

Heavy Quarks as a New Probe of the Quark Gluon Plasma (iFVTX) - \$1500k/year, 2006-2008

Heavy Ion Physics at the LHC using CMS - \$250k/year, 2006 - 2008

The First Precise Determination of Quark Energy Loss in Nuclei - \$250k/year 2008-2010



PHENIX Team Approach

Physics Leadership

- Within PHENIX Collaboration (EC, PWG convenors, DC members)
- Within the broader community (committees, reviewers)
- Bringing the community together (Workshop organizers, hosting visitors)

Significant Detector Contributions

- Muon Detectors, FVTX

Significant Analysis Contributions

- Leading muon analyses, correlation analyses, muon spin physics efforts
- Significant software efforts

Looking to the Future

- Forward Silicon Vertex Detector upgrade detector at RHIC
- Heavy Ion physics at the LHC
- JPARC spin physics

Active Pursuit of LDRD funds to support new directions

- FVTX, LHC physics, Energy Loss using E906

Active visitor program

- Full-time students at LANL, long-term visitors, theory visitors, seminar program

Encouraging Strong ties to T-Division

- Joint LDRDs, joint seminars

Personnel

Staff:** Melynda Brooks (0.9), Xiaodong Jiang (1.0), Jon Kapustinsky (0.5), Gerd Kunde (1.0), David Lee (0.8), Mike Leitch (1.0), Ming-Xiong Liu (1.0), Pat McGaughey (0.6), Walt Sondheim (0.55), Hubert vanHecke (1.0) (8.35 FTEs)

LDRD-supported Staff:** Gary Grim (P-23), Mark Prokop (AOT)

Post-Docs:** Sergey Butsyk, Carlos Munoz Camacho, Paul Constantin, Camelia Mironov, Anuj Purwar, Han Liu (6 FTEs)

Students and Full-Time Visitors:** Maria Castro, Hisham Albataineh (NMSU), Xiaorong Wang (NMSU), Zhengyun You (Peking), Michael Malik (UNM)

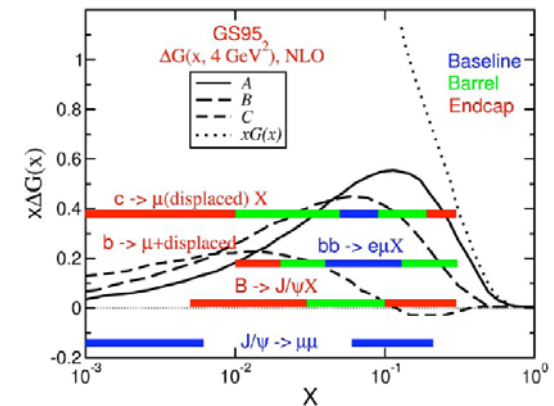
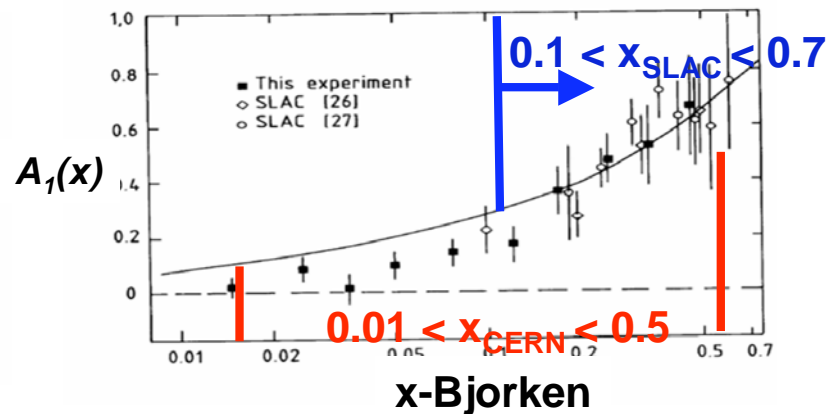
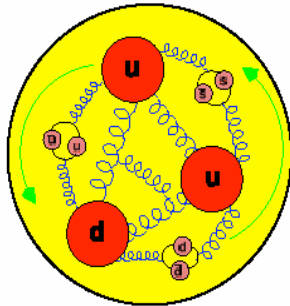
NSF Summer Interns: Samuel Fletcher, Michelle Adan

Personnel Changes:

- Xiaodong Jiang new staff hire
- Paul Constantin, Anuj Purwar, Carlos Camacho finished post-docs
- Han Liu hired mid-year, Lei Guo, Zhengyun You starting post-docs in March

**Supported partially by LDRD funds

Spin Physics Approach with RHIC



Polarized Proton-Proton collisions allow unique opportunity to look at gluon contributions to the proton's spin

$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} \sim \propto a_{gg} \cdot \Delta G^2 + a_{qg} \cdot \Delta q \cdot \Delta G + a_{qq} \cdot \Delta q^2$$

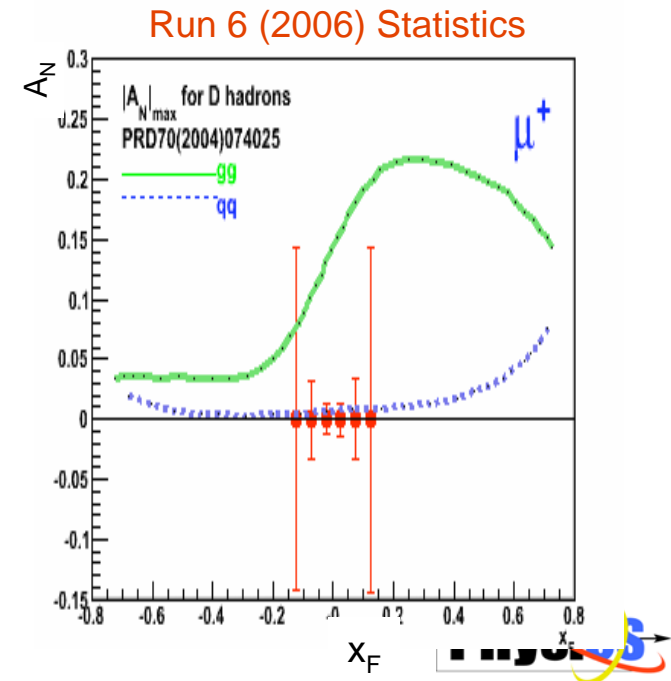
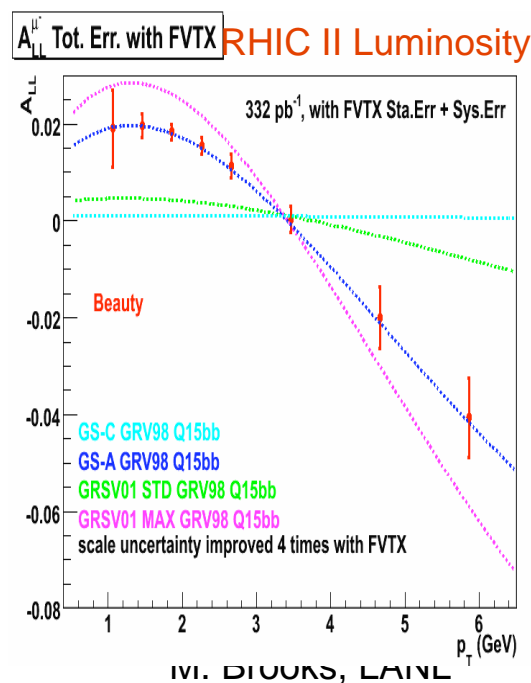
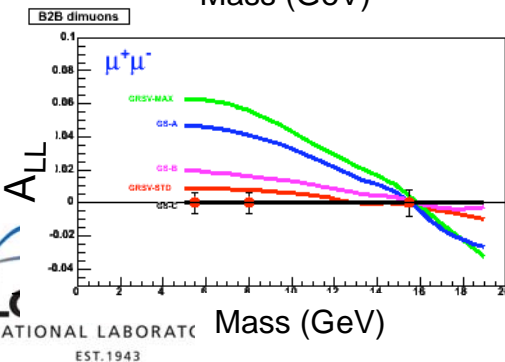
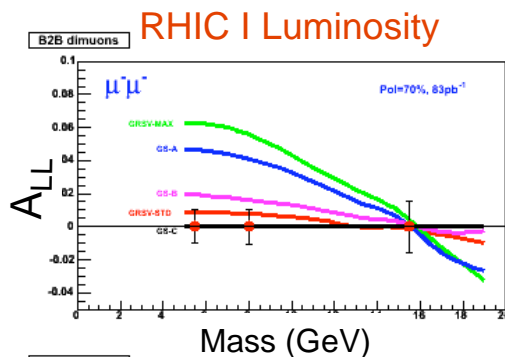
Forward plus central rapidity necessary to map out polarized distributions over x

W, Drell-Yan measurements at RHIC give access to sea quark contributions to the spin

Transversely polarized protons give access to Sivers functions, which should ultimately be able to be related to orbital angular momentum contributions to the proton's spin

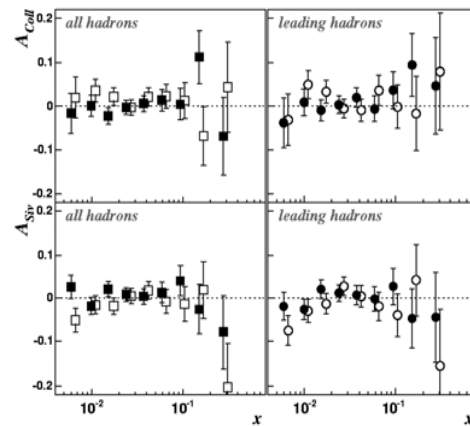
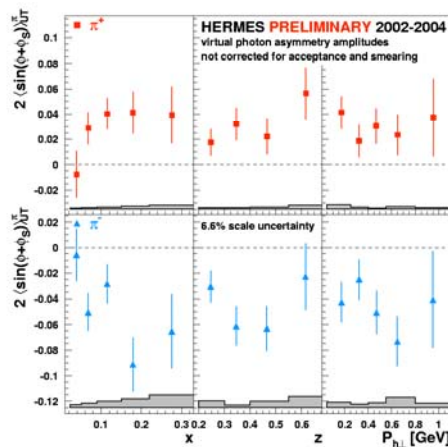
RHIC Spin - Polarized Gluon Distributions, Sivers

- Charm A_{LL} measurements give access to polarized gluon distribution functions
- Back-to-back dimuons (dominated by heavy flavor, different kinematic range and better statistics), single muons from heavy flavor (especially with FVTX detector)
- Charm A_N measurements give direct access to gluon Sivers function (gg production is dominant, no Collins effect possible)
- LANL has led efforts in all muon spin analyses to date and will lead proposed measurements below
- Ming Liu, Xiaodong Jiang, Han Liu primary workers

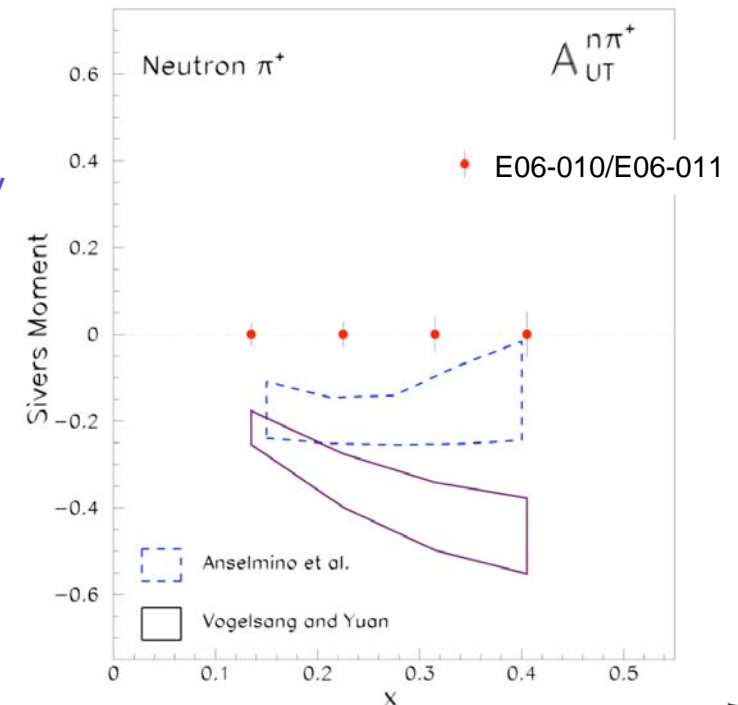


LANL Spin Program at JLAB

- Xiaodong Jiang hired in November, Co-spokesperson of 3 A-rated experiments, significant experience at JLAB
- Propose to continue some efforts at JLAB, especially on already-approved SSA measurement (take data in October 2008)
- Fraction of Xiaodong plus fraction of post-doc to lead experiment and participate in analysis, pursuing LDRD ER options (FY09 or later)
- Hermes polarized proton measurements give significant SSA in pion production, COMPASS sees no asymmetry in polarized deuteron measurement.
- Do u/d contributions cancel in deuteron?
- JLAB experiment gives access to d-quark's angular motion through polarized neutron single-spin asymmetry measurements.

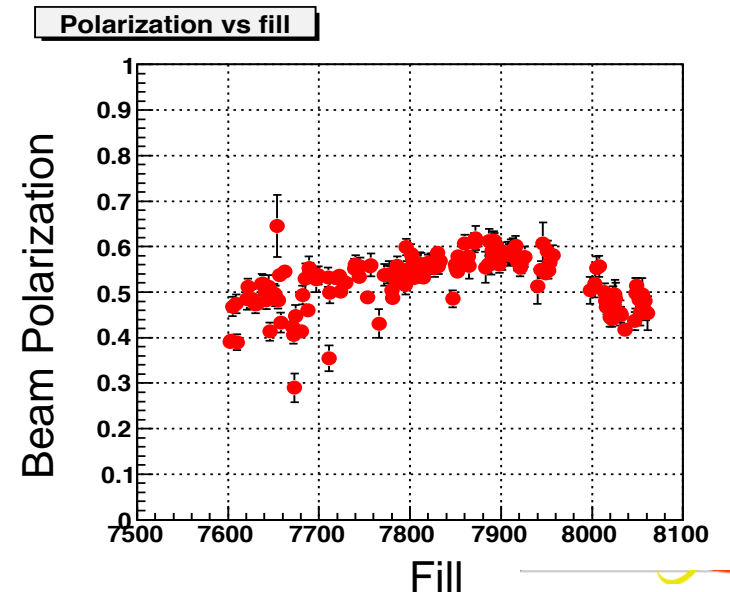
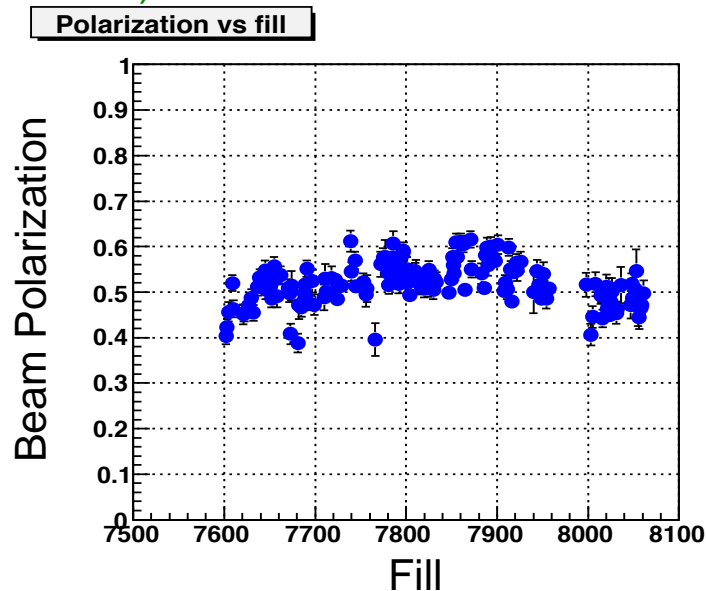
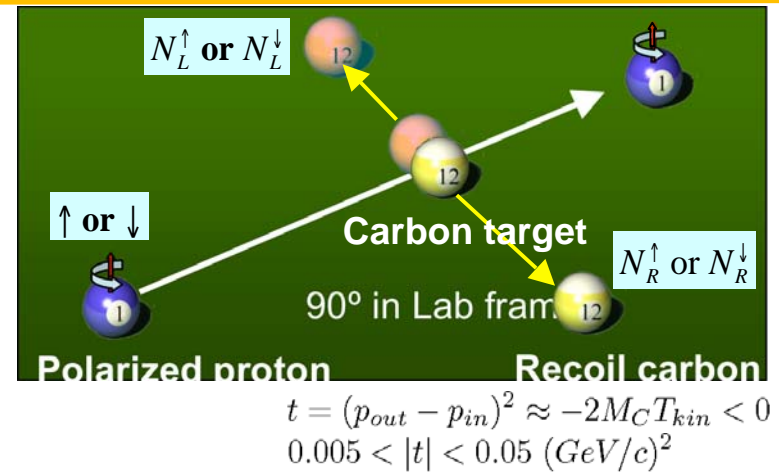


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RHIC Spin Highlights - Service

- Leading **single muon analysis efforts**
- Leaders in **optimizing muon arm performance** (critical for W, other high p_T programs)
- **SpinFest organizers**
- Performed CNI analysis necessary to extract **fill-by-fill polarization of RHIC beams**, necessary for all RHIC spin physics measurements, **new analysis significantly reduced systematic errors**
- **Han Liu, Carlos Camacho, Ming Liu contributors** (plus others on software)



RHIC Cold Nuclear Matter Approach

Cold Nuclear Matter Physics interesting in its own right:

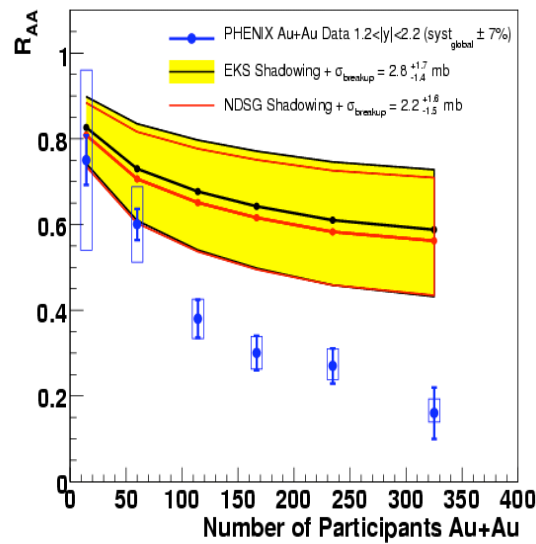
- PDFs modified in nucleus?, Energy loss?, Color Glass Condensate?

Measurement is *vital* for clean interpretation of Heavy Ion particle production

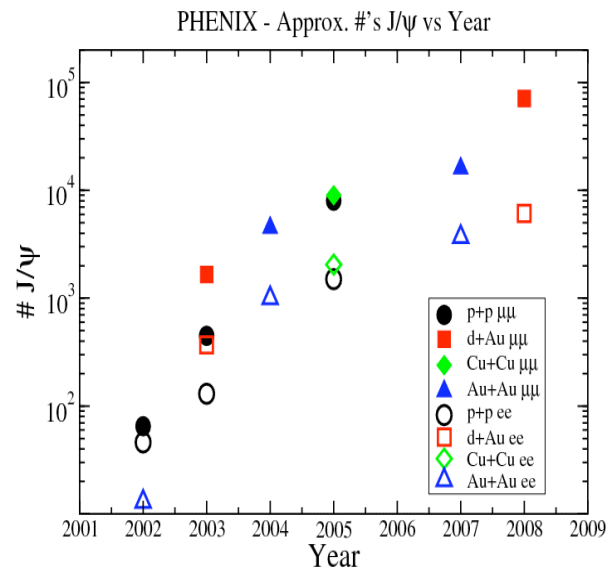
- LANL will continue to lead efforts in analyses, pushed hard for Run 8 d+au, provided PHENIX Run Coordinator (Mike Leitch)

Mike Leitch, post-doc primary workers

Run 3 dAu Extrapolation

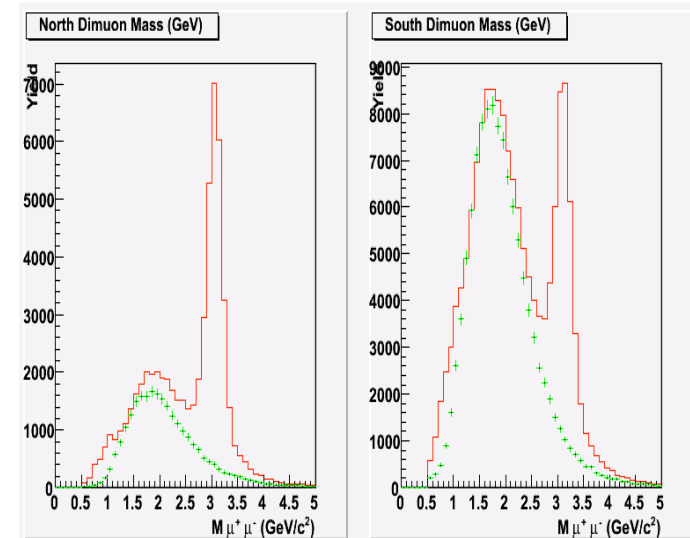


Run 8 Statistics



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Run 8 Online Analysis



Heavy Ion Program Approach

Understanding energy loss mechanisms in heavy-ion induced medium necessary to accurately determine properties of QGP

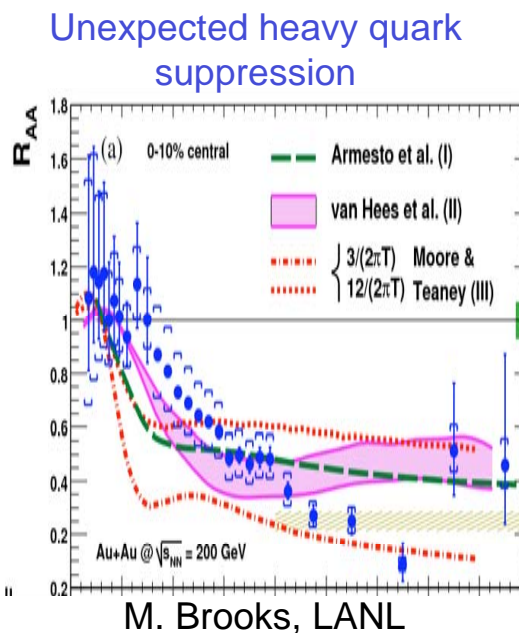
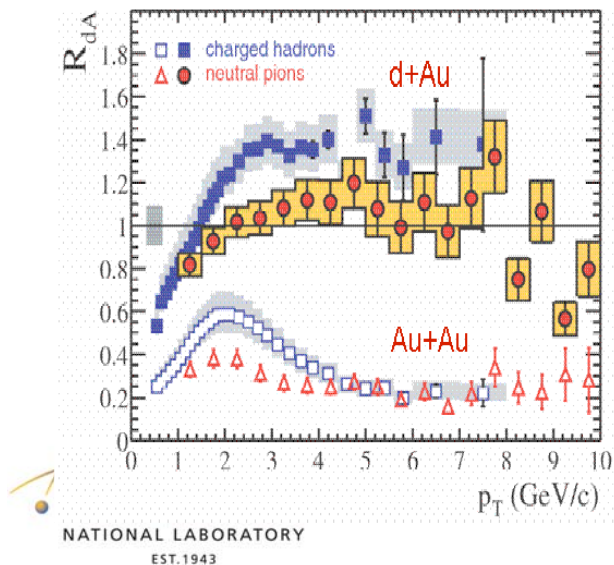
What role does screening play in the QGP?

What role does recombination play in particle production in AA collisions?

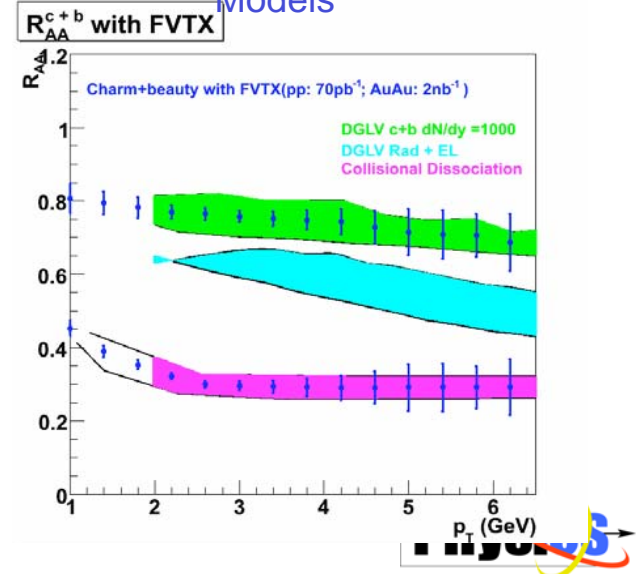
What new things can we learn at the LHC?

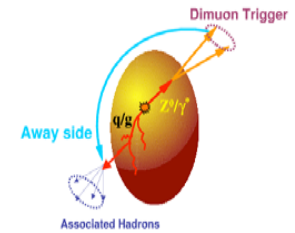
RHIC - Energy Loss Mechanisms in the QGP

- Although large pion suppression most-cited RHIC result confirming new matter, much not understood
- What energy loss mechanisms can explain both heavy and light quark suppression?
- What is causing depletion of away-side particles in 2-particle correlation measurements?
- Add precision heavy-quark measurements, new channels; remove ambiguity in correlations
- Melynda Brooks, Dave Lee, Pat McGaughey, Hubert vanHecke, post-docs primary workers



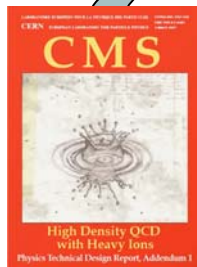
FVTX Separates Energy Loss Models



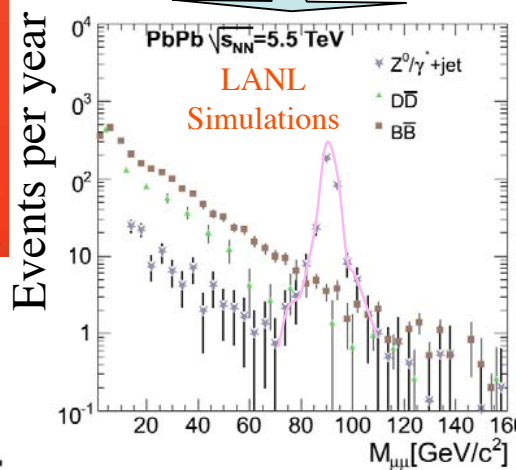


LHC Heavy Ion Opportunities

- **FY06-FY08 LDRD ER grant** (Gerd Kunde, Camelia Mironov, Maria Castro) allowed detailed study of CMS performance, *published in CMS Heavy Ion pTDR*
- **1st LHC data expected this year** -- officially join CMS this year
- **Critical to maintain efforts** to ensure strong future program at LHC
- **Proposed LDRD DR grant** : Experimental efforts in data analysis, develop QCD theory, bring expertise to realize the Pixel Luminosity Detector (PLT) for CMS
- **Propose DOE-funded 0.5 TSM + 1.0 post-doc for near-term** (if no LDRD)
- **Propose long-term transition to balanced efforts** between RHIC and LHC



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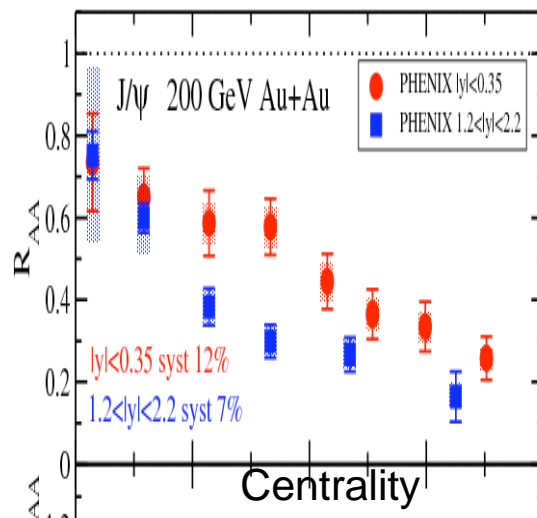
Important LANL Expertise

- HI Muon Reconstruction. and Analysis
- Pixel Technology and Bump Bonding
- Theory in pQCD and Lattice QCD
- Physics of Correlation Measurements

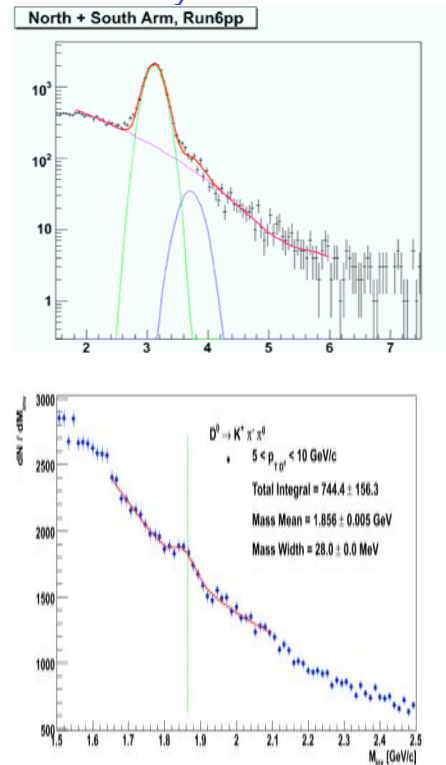
RHIC - Screening, Recombination

- J/ψ production in AuAu collisions shows suppression similar to CERN, unexpected rapidity dependence
- Is screening causing significant portion of suppression or not? --> measure suppression versus binding potential (J/ψ , ψ' , $\psi(2S)$)
- Does recombination play an important role in production? --> better open charm, flow?
- Melynda Brooks, Han Liu, Sergey Butsyk primary workers

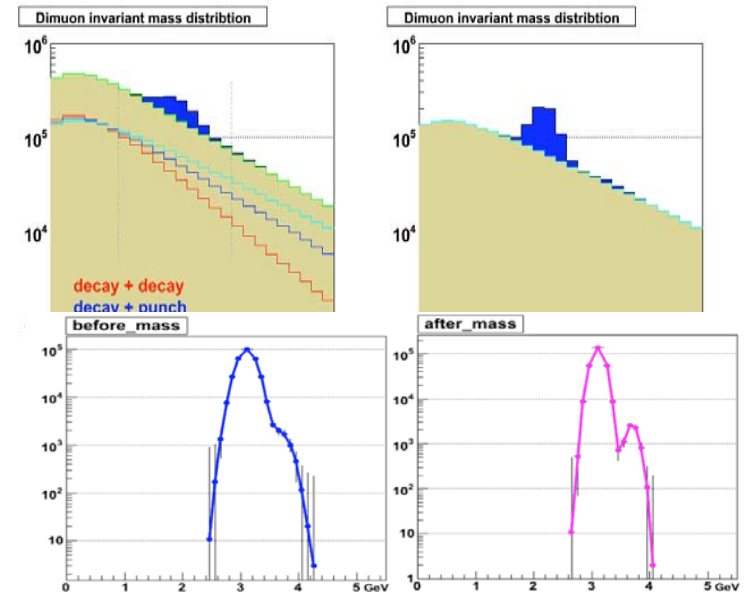
J/ψ Suppression in AuAu Collisions



New Measurements with
Today's PHENIX

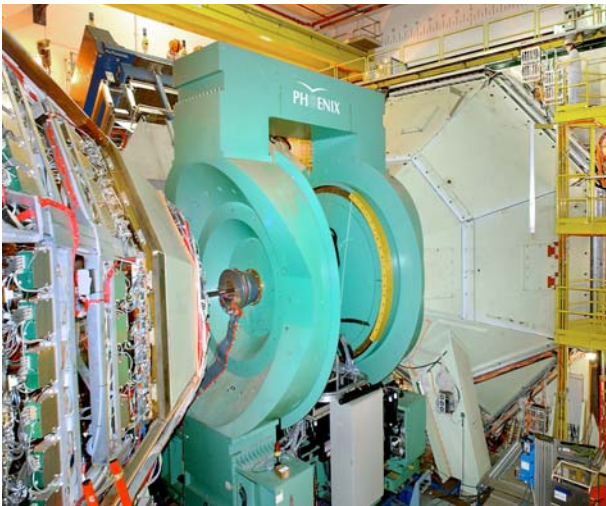


Measurement Capabilities
with FVTX



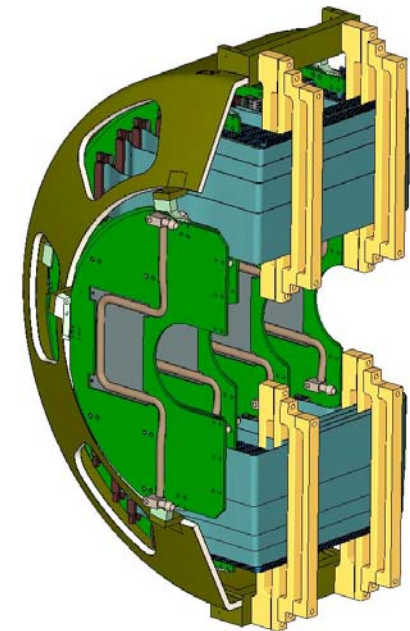
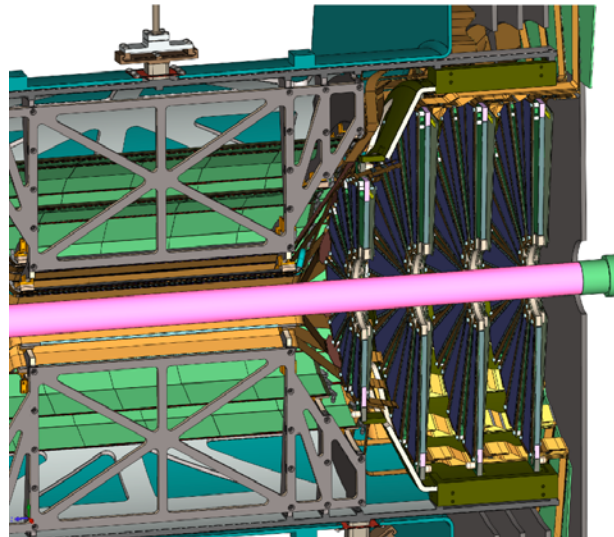
Providing the Tools Needed (MuTr, FVTX, Software)

- **Muon Trackers** - DC Member, provide several on-call expert shifts per run, coordinate and perform maintenance each shut down, working closely with Muon Trigger upgrade
- **FVTX/iFVTX** - significantly enhancing the future Muon Physics program by adding vertexing capability. Project managers, DAQ, sensor and readout chip.
- **Software** - most muon simulation and reconstruction software originated at LANL and performance optimization. Expect to continue this role for future measurements.
- **Many contributors to all efforts**



Muon System Support

FVTX Managers/Technical



LDRD: R&D, Early Data, Theory

Manpower Effort Estimates, FY09/FY10

Project	TSMs	PDs	Other
KB02 Analyses	3.0	1.70 (1.0)	
KB01 Analyses	1.5	0.80 (0.5)	
FVTX	2.0/ 0.2 project	1.5	~0.5 Engineer (project)
LHC (propose to maintain)	0.5*	1.0* (0.5)	
E906	0.40 (LDRD)		
Total	6.9/0.6	5.0 (3.0)	

- FY09 President's budget request covers ~6.9 staff plus 3.0 PD
- If proposed funding remains and we get no LDRD, we would need to reduce PHENIX analysis efforts to maintain others

Budget - FY08

Year	FY08	FY09	FY10			
		presidents	-5%	flat	+3.5%	proposed
KB01	\$949k	\$1000k	950	1000	1035	1168
KB01 FTE	1.8+1.0PD	2.0+1.0PD	1.8 +0.5PD	2.0+0.5PD	2.0+1.0PD	2.0+2.0
KB02	\$2280	\$2498k	\$2373k	\$2498k	\$2585k	\$2718k
KB02 FTE	4.2+2.0PD	4.9+2.0PD	4.6+1.0PD	4.9+1.5PD	4.9+2.0PD	4.9+3.0PD
RHIC HI Analyses		<i>Some reduction</i>	<i>Reduced More</i>	<i>Reduced More</i>	<i>Some Reduction</i>	<i>good</i>
Spin +CNM analyses		<i>RHIC + JLAB?</i>	<i>No JLAB/red. RHIC</i>	<i>No JLAB</i>	<i>RHIC + JLAB?</i>	<i>good</i>
E906		<i>LDRD</i>	<i>LDRD</i>	<i>LDRD</i>	<i>LDRD</i>	<i>LDRD</i>
FVTX		<i>good</i>	<i>good</i>	<i>good</i>	<i>good</i>	<i>good</i>
LHC HI	<i>LDRD</i>	<i>maintain</i>	<i>maintain</i>	<i>maintain</i>	<i>maintain</i>	<i>maintain</i>

LDRD funds
0.75TSM+1
PD ?

LDRD funds
0.40 staff + ?

lose 2.0 PD
or 0.7 staff

lose 1.0 PD

Some reduced analysis

robust FVTX,
analysis
+ LHC

Key Roles

Physics working groups: all, Brooks, Leitch (Heavy-quark Physics Convener & Speakers Bureau)

Executive Council: Leitch

Single Muon Working Group Convenor: Liu

Paper writing: Brooks, Constantin, Leitch, Liu, McGaughey, Purwar

Internal paper review committee: Kunde, Lee, Leitch, Liu, McGaughey, van Hecke

Muon Tracking operations & repairs: many

Run coordinator: Leitch (run07, run08)

Period coordinator: Leitch, Liu

FVTX Project Managers: Brooks, Lee

VTX Mechanical Liaison: Lee

Integration & Engineering, VTX Mechanical Lead Engineer: Sondheim

Detector Council Members: van Hecke(past MVD), Brooks(past muon),

Leitch(past muon, current muon), McGaughey (past muon)

Subsystem manager: Lee (muon mechanical)

PHENIX Physics Impact Panel for QM05 – Leitch

Co-Convenor of RHIC 11 pA/Forward physics group – Leitch

NSAC Long Range Planning Committee: Lee

APS Hadron Physics Topical Group Executive Member - Leitch



LDRD PIs: McGaughey (DR, \$1.25M/yr), Kunde (ER, \$250k/yr)

Community Services

Organized several [FVTX and LDRD silicon vertex detector workshops](#)

Organizer for [3-week spin workshop at BNL](#) (Liu), [3rd annual Spinfest at RIKEN](#) (Liu)

Organized 3 successive Annual Muon Workshops (summer '03, '04, '05, ~60 attendees)

Organized PHENIX Forward Physics Workshop (summer '07, ~50 attendees)

Many staff members reviewers for various publications, grant proposals, technical projects

[Host for students, postdocs, staff](#) from other institutions for physics analyses:

[NMSU](#) - Xiaorong Wang, Han Liu, Hisham Albataineh ([in residence with LANL group](#))

[UNM](#) – Michael Malik working with us and ([in residence at LANL](#))

[Peking University](#) – Zhengyun You ([in residence at LANL for approximately 1 year](#))

[Saclay](#) - Hugo Pereira; [UNM](#) - Imran Younus

[UIC](#) - Miroslav Mihaylov; [NMSU](#) -Alberto Canabal-Rey

Many [former postdocs or staff](#) now contributing elsewhere – John Sullivan, Jane Burward-Hoy, Ben Norman (LANL); David Silvermyr (ORNL); Rusty Towell (ACU); Paul Reimer (ANL); Shekhar Mishra (FNAL) to name a few.

Spinoffs

Muon Radiography contributions: (Pat McGaughey)

Preamplifier electronics development based on muon spectrometer experience



Capital Equipment Request

Silicon repair/development tools

We are leading the FVTX construction project for PHENIX and expect to play a major role in the construction of luminosity telescope for CMS. Both of these projects require precision tools to perform wire bonding and to electrically probe microscopic detector / readout elements. In our past silicon detector projects, much of this work has been farmed out to industry or facilities at Fermilab. While that process is sensible for mass construction, it is time consuming and expensive for immediate testing and repair needs. This hardware also gives us the in-house capability to identify the more subtle design and processing problems that arise, and invoke mitigation strategies before we proceed to mass construction.

Therefore, **we request \$88K in capital equipment funds** for a small microdetector inspection and repair station that would be located at LANL. The station would consist of :

- Refurbished wire bonder (\$20K)
- Probe station with microscope and camera (\$60K)
- Two micropositioners (\$3K)
- Dark Box (\$5K)

With this microdetector station we would be able to :

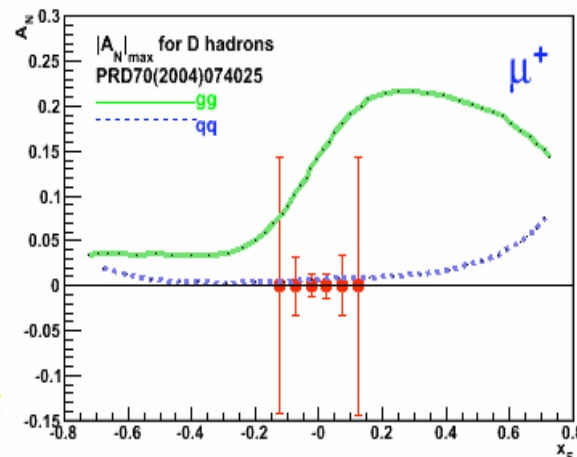
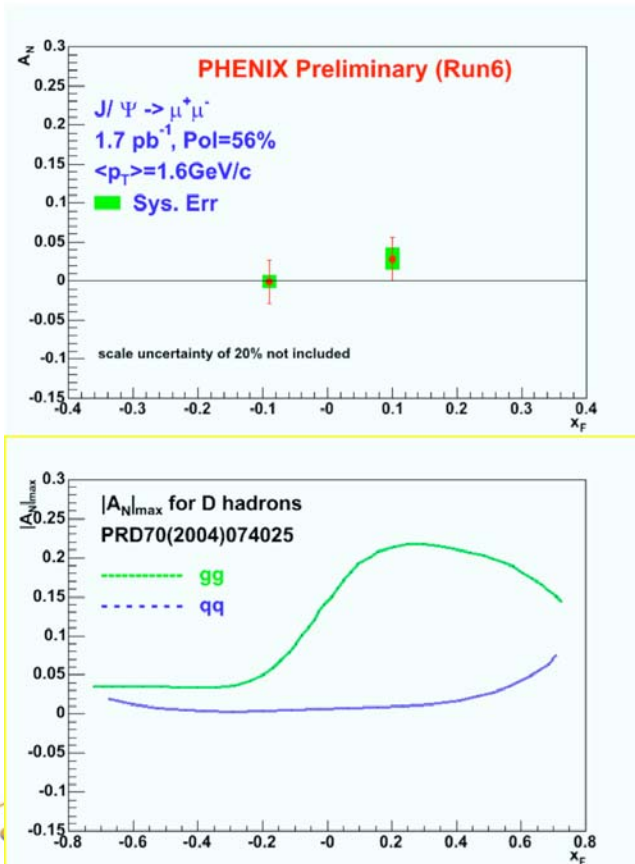
- Wirebond prototype detectors, readout chips and cabling.
- Inspect and test components and detector assemblies.
- Remove and repair damaged or incorrect wire bonds.

This would greatly improve our in house capability to quickly test and repair these custom detector components.

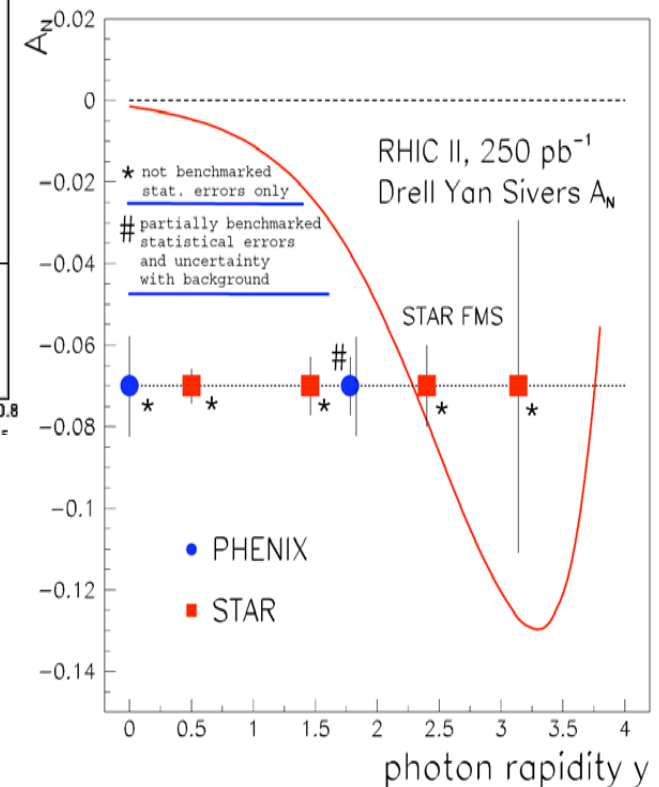
Backups

RHIC Spin Highlights - Sivers Functions

- Charm A_N measurements give direct access to gluon Sivers function (gg production is dominant, no Collins effect possible)
- Nothing currently known about gluon Sivers function so any measurement will help constraint theory



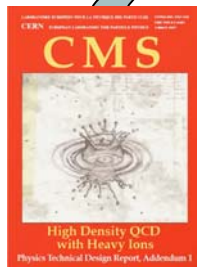
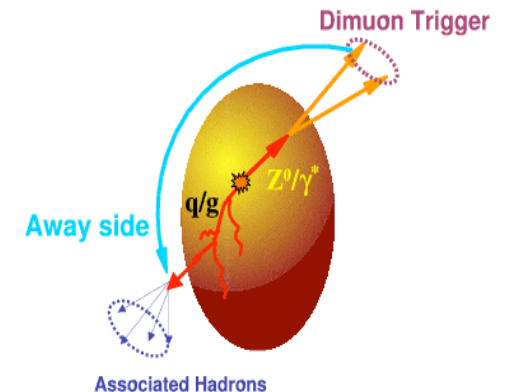
RHIC II Drell Yan Projections



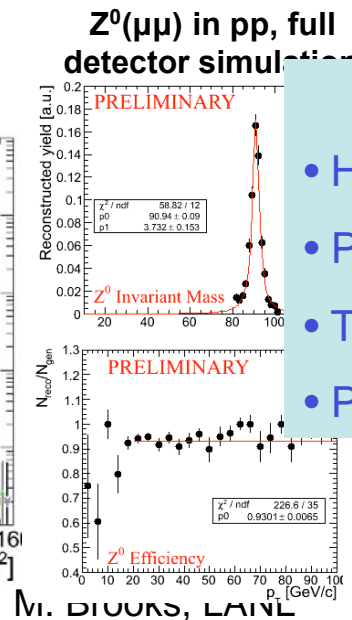
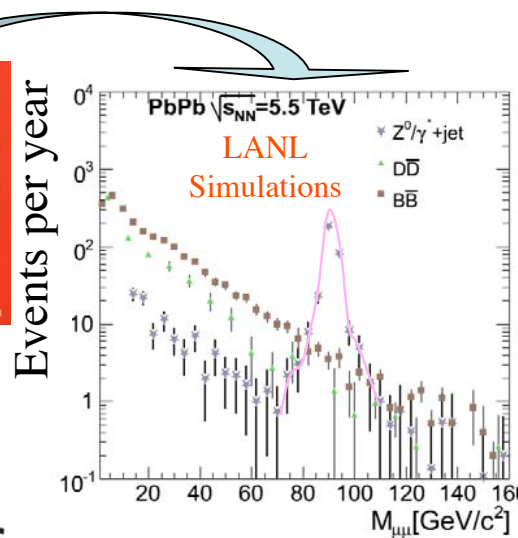
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LHC Heavy Ion Opportunities

- LHC energies, luminosities offer unique opportunity to measure jet energy, provide unbiased trigger for jet studies
- LDRD ER grant allowed detailed study of CMS performance, study of statistical significance of measurement, *published in CMS Heavy Ion pTDR*
- Proposed LDRD DR grant to continue efforts into data analysis, expand LHC physics program in experiment and theory, bring expertise to collaborate on building the Pixel Luminosity Detector (PLT) for CMS
- Gerd Kunde, Camelia Mironov, Maria Castro primary workers



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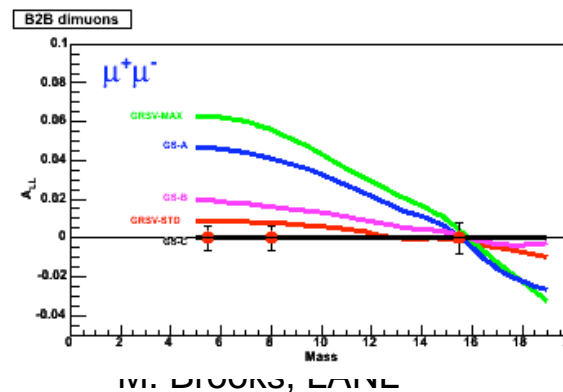
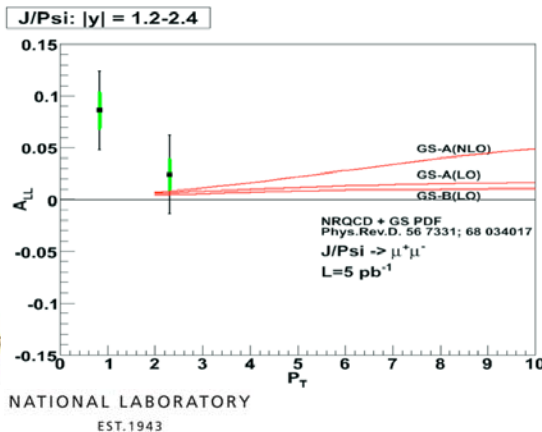
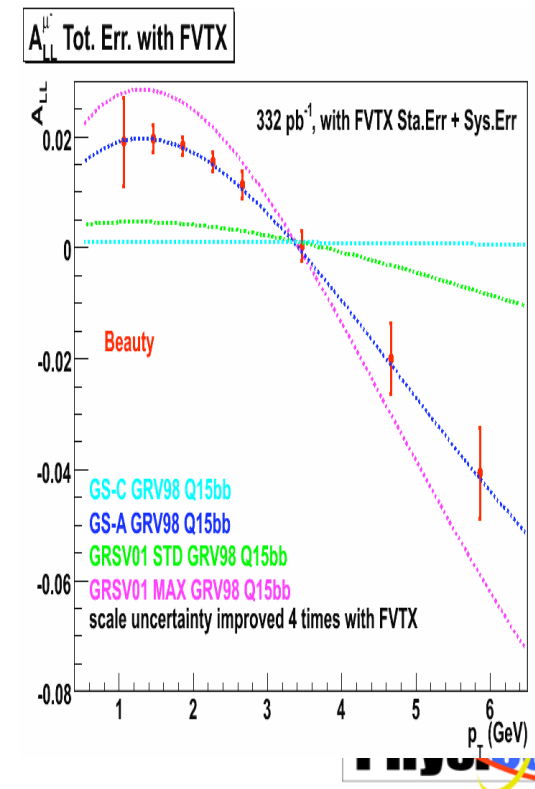
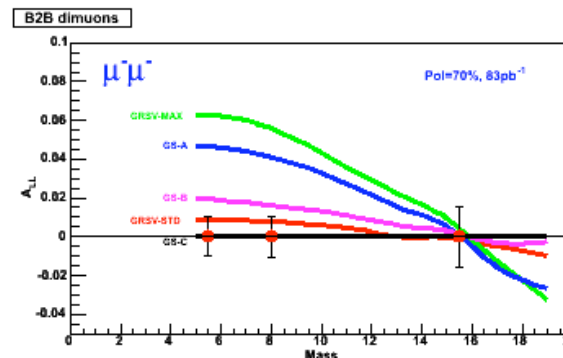
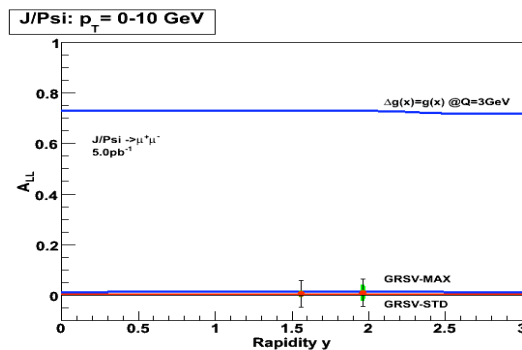


Important LANL Expertise

- HI Muon Reconstruction. and Analysis
- Pixel Technology and Bump Bonding
- Theory in pQCD and Lattice QCD
- Physics of Correlation Measurements

RHIC Spin Highlights - Polarized Gluon Distributions

- Charm A_{LL} measurements give access to polarized gluon distribution functions
- J/ψ statistics allow discrimination against GRSV-max (ruled out by pion data also), but not separation of GS-A,B,C, std.
- Better potential with back-to-back dimuons (dominated by heavy flavor, different kinematic range and better statistics), single muons from heavy flavor (especially with FVTX detector)

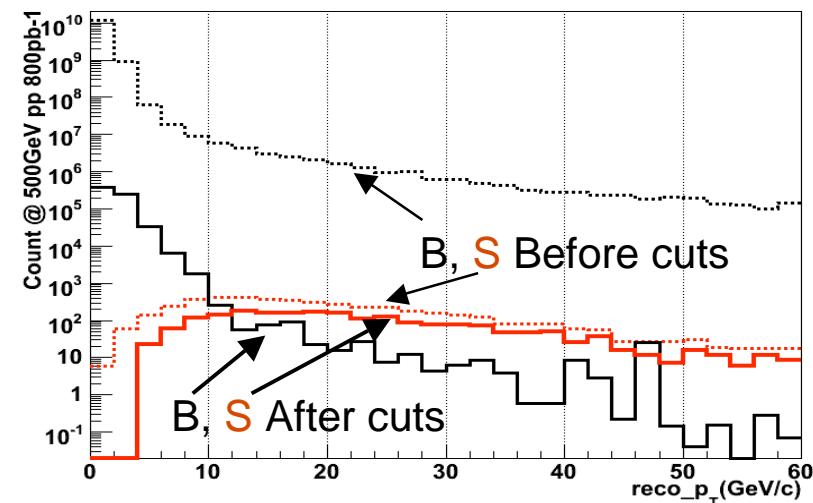
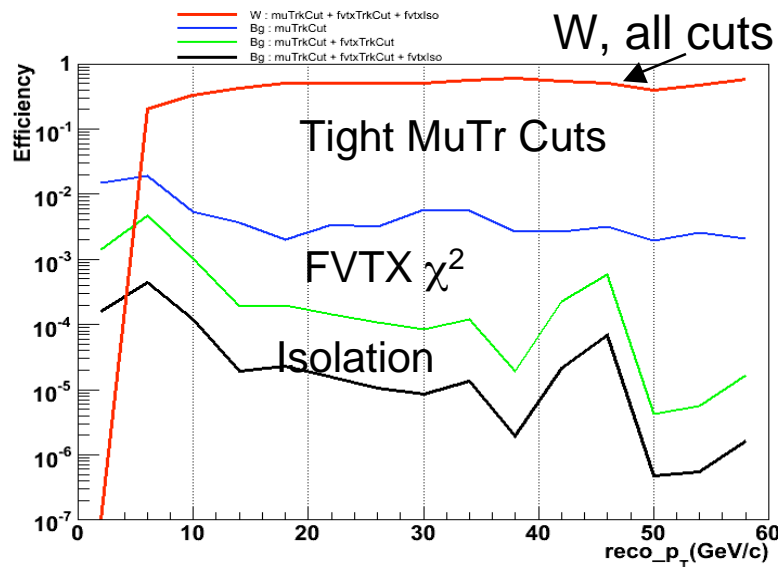
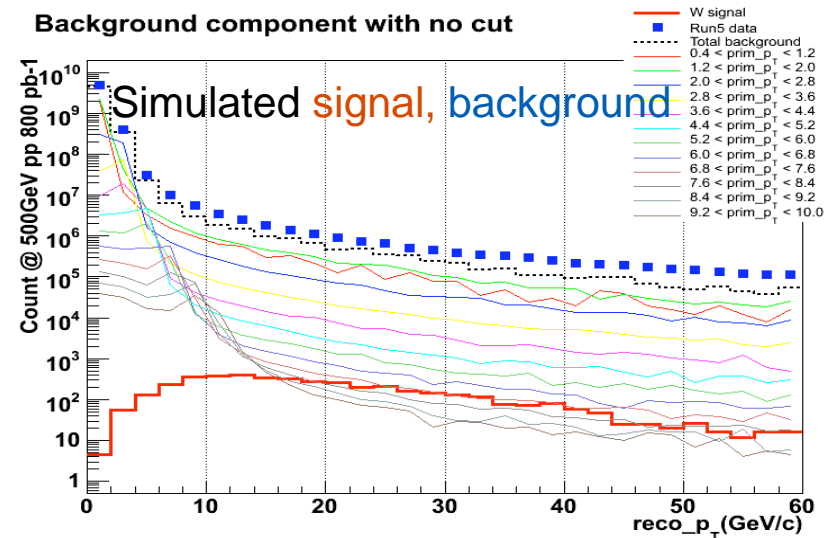


W Background Offline Rejection

Single muon spectrum contributions from:

- $W \rightarrow \mu X$
- Hadron punch-throughs, decays
- Mis-reconstructed hadrons
- Tight MuTr cuts plus FVTX cuts improve signal:background by $\sim 10^5$

Background component with no cut



(Continued) New Initiatives

LDRD DR submitted this year to continue LHC efforts:

- Joint P/T-division submission
- Analysis of first p+p and A+A data, theoretical advancement of HI modeling
- Would support fraction of some staff plus post-doc efforts
- Ranked 5 out of 60 proposals submitted to P-division
- Ranked 8th in T-division
- If DR not granted, will also try for ER

Will continue to seek LANL-funded, named post-docs

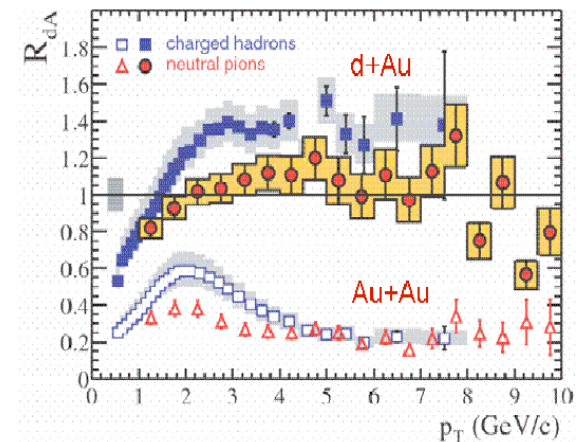
- Hire this year made it to final ranking for Director's funding
- Re-submit next year, search for more outstanding candidates

Current E906 LDRD will extend through FY10

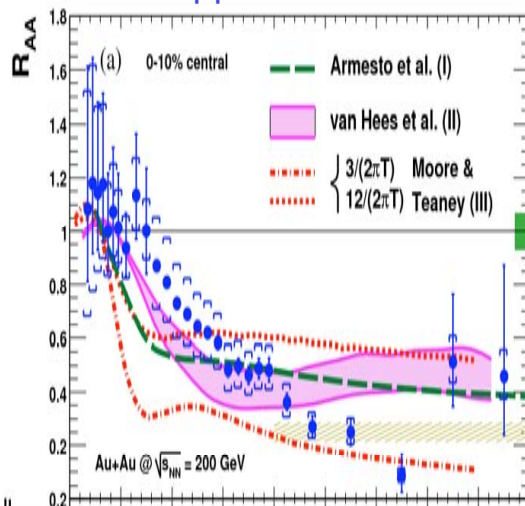
- 40% TSM plus capital coverage (or equivalent in TSM plus PD)

RHIC - Energy Loss Mechanisms in the QGP

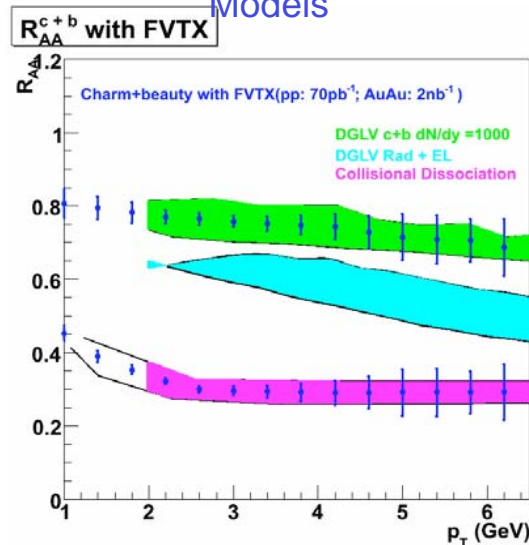
- Although large pion suppression most-cited RHIC result confirming new matter, much not understood
- What energy loss mechanisms can explain both heavy and light quark suppression?
- What is causing depletion of away-side particles in 2-particle correlation measurements?
- Add precision heavy-quark measurements, new channels; remove ambiguity in correlations



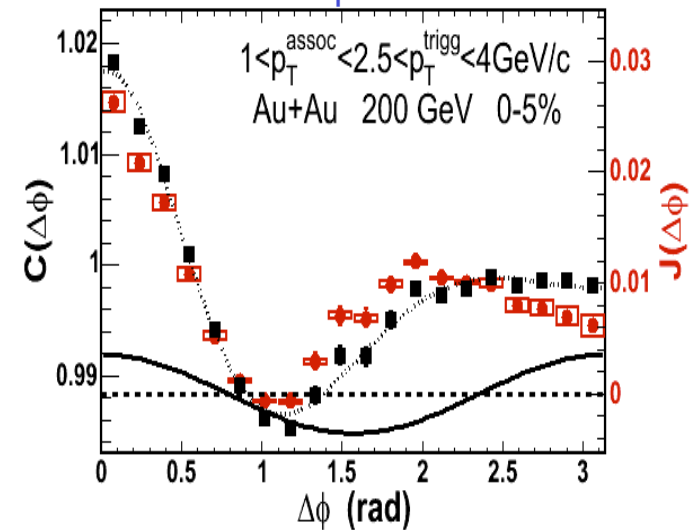
Unexpected heavy quark suppression



FVTX Separates Energy Loss Models

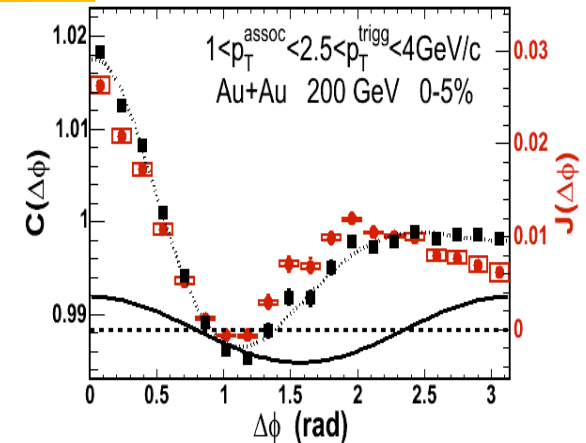


Unexpected particle correlation shapes

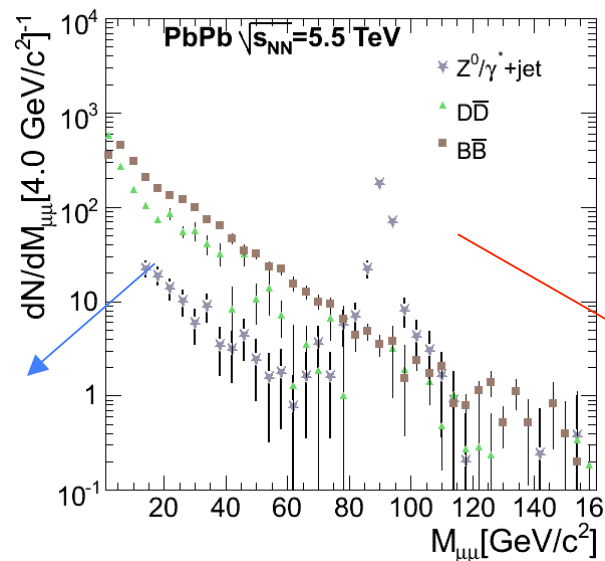
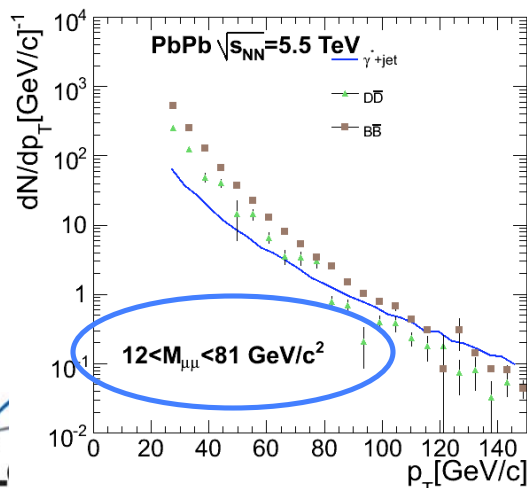


LHC Heavy Ion Opportunities

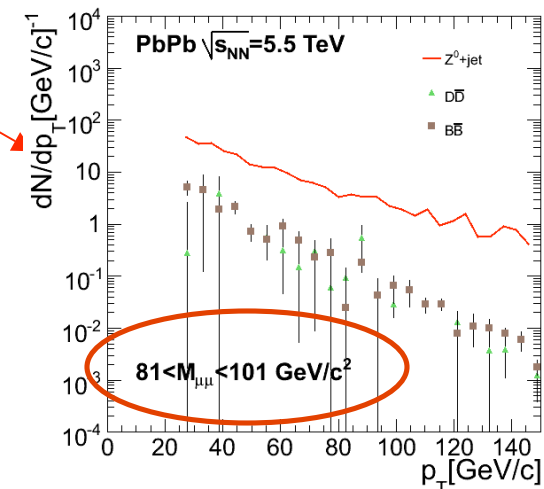
- LHC energies, luminosities offer unique opportunity to measure jet energy, provide unbiased trigger for jet studies
- LDRD ER grant allowed detailed study of CMS performance, study of statistical significance of measurement
- Proposed LDRD DR grant to continue efforts into data analysis, expand LHC physics program
- Gerd Kunde, Camelia Mironov, Maria Castro primary workers



Signal, Background in Continuum



Signal, Background in Z mass region



M. Brooks, LANL